Hindawi
International Journal of Chemical Engineering
Volume 2022, Article ID 6932320, 7 pages
https://doi.org/10.1155/2022/6932320

*Research Article*

# Biodiesel Production from Waste Animal Fat by Transesterification Using $H_2SO_4$ and KOH Catalysts: A Study of Physiochemical Properties

**Nasim Hasan** [1] **and M. Venkata Ratnam** [2]

[1]*Department of Mechanical Engineering, Mettu University, P.O. Box 318, Mettu, Ethiopia*
[2]*Department of Chemical Engineering, Mettu University, P.O. Box 318, Mettu, Ethiopia*

Correspondence should be addressed to M. Venkata Ratnam; mvratnam81@gmail.com

Received 12 January 2022; Revised 2 March 2022; Accepted 14 March 2022; Published 26 March 2022

Academic Editor: Fernanda Casciatori



Biodiesel is marketed as a long-term renewable fuel that may partially replace fossil fuels in transportation while also helping to reduce global warming. The current study is focused on using waste animal fat as a feedstock for biodiesel production. Sulfuric acid ($H_2SO_4$) and potassium hydroxide (KOH) are used as catalysts, with methanol as an alcohol. Temperature at 60°C, reaction time 2 hrs for acid catalyst, and 55°C, reaction time 90 min for base catalyst with a methanol to oil ratio of 5 : 1 are the experimental and optimized process conditions. With the $H_2SO_4$ catalyst, the biodiesel yield was 65.7%, while with the KOH catalyst, it was 48.8%. The ASTM standards are used to compare and study the physicochemical characteristics. This study offers an environmentally friendly solution to a global problem of atmospheric pollution, and at the same time, it shows a commercial alternative to reduce the ecological impact caused by waste animal fat.

## 1. Introduction

Global demand for fossil fuels has risen dramatically as a result of fast technological progress and population growth [1]. This trend is anticipated to continue, with estimates from the US Energy Information Administration (EIA) predicting a 28 percent increase in energy consumption between 2015 and 2040 [2]. Biodiesel is one of the newest alternatives to fossil fuels that has attracted a lot of interest due to its similarities to diesel [3]. It has the benefit of emitting low amounts of $SO_x$ while improving lubricity and reducing engine damage [4]. According to the International Energy Agency, bioenergy must increase by up to 25% by 2025 and continue to develop [5]. By 2050, biofuels are anticipated to account for 30% of the world's road transportation fuel mix [1, 5]. The world's growing economy would necessitate more energy use. Rapid technological development and population growth are driving global demand for fossil fuels. As a consequence of mounting concerns about fossil fuels' environmental incompatibility as a result of rising $CO_2$ emissions, a continual quest for alternative fossil fuels has begun [1]. One of the most intriguing and rapidly expanding uses for biofuels and biodiesel is energy generation. Existing diesel engines may run on biodiesel without any substantial changes. Biodiesel has higher oxygen content and a lower carbon-to-hydrogen ratio than conventional diesel. This highlights the major benefits of biodiesel, such as lower particulate matter emissions and lower sulfur, hydrocarbon, and carbon monoxide content.

Biodiesel is made up of monoalkyl esters of long-chain fatty acids that are made from oil with the help of an acid, base, or enzyme catalyst [3, 6, 7]. The primary feed stock can be from food sources including coconut oil, soybean oil, and used vegetable oil, as well as nonedible sources such as jatropha, algae, and rubber seeds [8–10] [11–13]. A lot of studies are now being carried out on the use of nonedible oil because of the issue of food security. Animal fats are generally formed of a mixture of triglycerides, proteins, water,

and diverse minerals [14]. Animal byproducts are created in large quantities as part of the meat and poultry production cycles. After being rendered, edible resources are processed in a range of food and feed-related enterprises.

Ethiopia has a reasonably affluent population. Ethiopia's livestock population is estimated at 52 million cattle (the highest in Africa), 27 million sheep, the third most in Africa, and 23 million goats, the third most in Africa [3]. When compared to vegetable oils, the wastes from cattle and sheep slaughtered for meat production have a high fat content [15]. Because of its high fat content, one option to recover this waste is to use it as a fuel for biodiesel synthesis [4, 13, 16]. The absence of adequate waste disposal by animal meat processing facilities and food processing/service facilities provides a great opportunity to create biodiesel from these very inexpensive raw materials. The use of waste animal fat (WAF) as a feedstock for biodiesel synthesis not only enhances biodiesel supply but also eliminates the need for its disposal.

Since the price of the raw material is the major cost in biodiesel production. The development of environmentally and economically feasible biodiesel is becoming a key concern, and animal fat waste might help achieve this objective. The most practical method for manufacturing biodiesel on a large scale has been determined to be acid and base catalyzed processes. As a result, the current study utilizes WAF as a feedstock for biodiesel synthesis, utilizing acid and base catalysts, and compares the resulting biodiesel to commercial diesel.

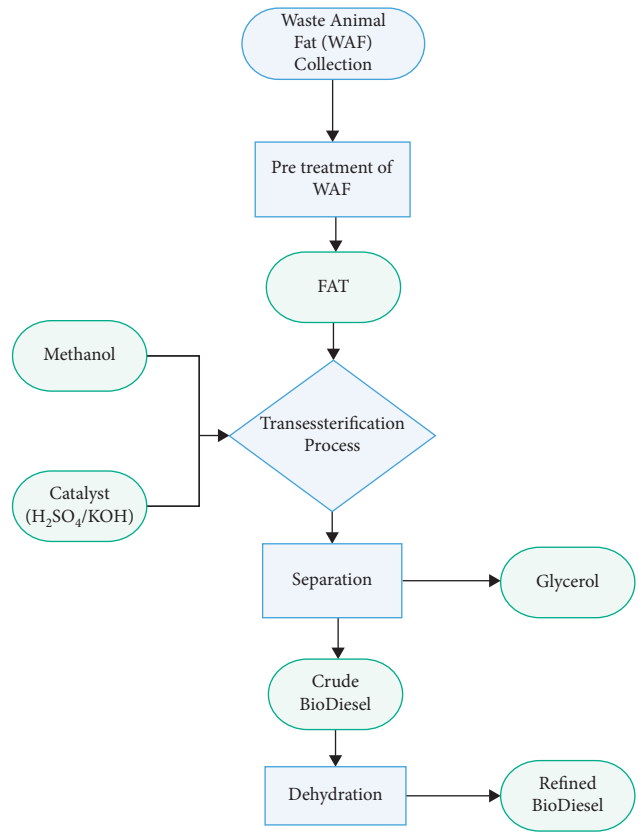



Figure 1: Schematic diagram of the biodiesel production methodology.

## 2. Materials and Methodology

### 2.1. Biodiesel Production from Waste Animal Fat

*2.1.1. Preprocessing of WAF and Extraction of Fat.* All the chemicals used are of analytical grade, and the feed stock waste animal fat was collected from meat processing wastes at the animal slaughterhouse. To increase biodiesel production, the acquired fat must be preprocessed before being exposed to the transesterification procedure. This involves eliminating nonfatty macroresidues and water content in fats, adjusting the pH, and liquefying them for easier handling. Fatty acids that separate from glycerol during hydrolysis are known as free fatty acids. Any fat with less than 15% FFA is referred to as yellow grease because of its yellowish hue [17]. Brown grease has a brownish black color and is composed of highly oxidized fats with FFA levels above 15%. Fat is extracted using a thermal method in this study, which includes melting the fat into liquid and pushing it out of the matrix using heat.

*2.1.2. Transesterification of WAF.* Figure 1 gives you the overview of the process adopted in this study. In the reaction chamber, acid ($H_2SO_4$) and base (KOH) catalysts employed separately to react with alcohol and fat molecules. The chamber heat was increased gradually to maintain the constant temperature. It runs with the best process parameters and a stop watch to keep track of reaction time. The molar ratio (1 : 1 to 1 : 6), catalyst concentrations of 0.1 to 2.0 wt%, temperatures (30–60 C), and time durations of 1 to 4 hrs were used. Following transesterification, the reaction mixture must be purified in order to meet biodiesel quality requirements [18]. Gravity decantation was used to separate the reaction products into biodiesel and glycerol, and the biodiesel was then water washed and dried. The water washing was done with 5% (v/v) hot water at 60 C for 15 min. To ensure that all residues were removed, the washing operation was repeated four times. After water wash, the biodiesel is dried at 110 C.

The biodiesel yield was calculated as shown in the following equation:

$$\text{yield}\,(\%) = \frac{\text{mass of the biodiesel}\ (\text{g})}{\text{mass of the fat taken}\ (\text{g})} \times 100. \quad (1)$$

*2.2. Properties of the Biodiesel.* Stringent quality assurance criteria are required for the successful commercialization and market acceptance of biofuels. The properties of biodiesel indicate if it is appropriate for the engine's performance, longevity, and emissions. Acid number, calorific value, viscosity, density, flash point, fire point, cloud point, pour point, and other characteristics distinguish biodiesel.

*2.2.1. Acid Number.* The acid number or acid value of edible oils or their esters reflects the amount of free fatty acids

(FFAs) and mineral acids (negligible) in the sample (Gokul *R*. [4]). The biodiesel sample (0.5 mL) was treated with a solution comprising 95% ethanol and diethyl ether in equal parts. Using phenolphthalein as an indicator, the resultant mixture was titrated with 0.1 M KOH. The following equation is used to calculate the acid value of biodiesel:

$$\text{acid number of biodiesel}\left(\frac{\text{mg KOH}}{\text{g}}\right) = 56.1 \times \text{normality of the KOH solution} \times \frac{\text{volume of KOH used}}{\text{weight of the sample taken}}. \tag{2}$$

*2.2.2. Kinematic Viscosity.* The kinematic viscosity determines the degree of atomization that biodiesel has. The biodiesel samples were heated to $40^0$C in a redwood viscometer no.1. The sample was filtered to eliminate dust and other solid material in the oil. The viscometer was turned to its normal vertical position. The suction force was applied to the thinner arm to draw a sample slightly above the upper timing mark. The afflux time was measured by timing the flow of the sample as it flowed, the upper timing mark was recorded. This procedure was repeated in triplicate. The amount of time it took to collect 50 mL of samples was recorded. The viscosity of the sample is calculated as follows:

$$\text{visocity}\left(\frac{\text{mm}^2}{\text{sec}}\right) = (A \times \text{time}) - \frac{B}{\text{time}}, \tag{3}$$

where A and B are two constants particular to the redwood viscometer. When the time taken is less than 100 seconds, $A = 0.26$ and $B = 179$; otherwise, $A = 0.24$ and $B = 50$.

*2.3. Determination of Density.* Density was measured by using the density meter at 298K. Density was calculated using the following equation:

$$\text{density of the biodiesel sample} = \frac{W_3 - W_1}{W_2 - W_1} \times \text{density of water}. \tag{4}$$

Where $W_1$ is the weight of empty bottle, $W_2$ is the weight of empty bottle with water, and $W_3$ is the weight of empty bottle with sample.

*2.4. Flash and Fire Points.* The flash point is an important indicator for fuel production that defines the lowest temperature at which the vapors of the material ignite. Hence, this value indicates the safety of the fuel for its transportation, storage, and handling. The sample was placed in the flash and fire point apparatus, along with a cotton thread. A gas burner was used to heat the biodiesel. Another lit cotton thread was dragged over the old thread's surface. The flash point was the temperature at which the first thread produced a spark, and the fire point was the temperature at which the thread started to burn.

*2.5. Cloud and Pour Point.* Cloud point is defined as the temperature at which a cloud of wax crystals first appears in a liquid when it is cooled under controlled conditions during a standard test. Ice was used to fill the cloud and pour point apparatus. Biodiesel was poured into the glass containers. The cloud point was defined as the temperature at which the paraffin in biodiesel began to solidify and cloudiness occurred. The temperature at which the biodiesel turns semisolid was used to calculate the pour point. The cloud point (CP) and pour point (PP) of biodiesel samples are determined according to ASTM D2500-91 and ASTM D97-96, respectively.

*2.6. HHV.* The HHVs of biodiesel samples are measured in a bomb calorimeter according to the ASTM D2015 standard method.

*2.7. Ash Content.* The biodiesel sample (5 g) was placed in a muffle furnace in a preweighed quartz crucible ($450^0$C preheated). Once the sample had completely burned to ash, the crucible was removed. The crucible was weighed again after cooling. The following formula can be used to calculate the ash content:

$$\%\,\text{ash content} = \frac{\text{weight difference of the crucible before and after heating}}{\text{weight of the biodisesel}} \times 100. \tag{5}$$

*2.7.1. Cetane Number (CN).* The cetane number (CN) of biodiesel samples is determined according to the ASTM test. This test method measures the ignition delay and utilizes a constant volume combustion chamber with direct fuel injection into heated, compressed air.

*2.8. Determination of Moisture Content of Oils.* Oils were weighed primarily, and they were dried in an oven at $105^0$C for 24 hours, and the final weight was taken. The procedure was repeated in triplicate and recorded. The percentage of moisture in the seed was calculated using the following equation:

$$\%\, moisture = \frac{W_i - W_f}{W_i} \times 100, \quad (6)$$

where $W_i$ is initial weight of oil sample (before drying) and $W_f$ is final weight of oil sample after drying.

## 3. Results and Discussion

*3.1. Preprocessing of WAF.* A total of 760 g of slaughterhouse fat was rendered for 30 min at 265°C. After the melted fat is filtered, the physiochemical properties of the fat are assessed in Table 1. The fat obtained from WAF yields around 93%. Figure 2(a) shows how waste animal fat (WAF) is collected for use in biodiesel manufacturing, and Figure 2(b) shows the fat extracted from WAF.

*3.2. Transesterification of Refined WAF.* Two distinct catalysts were used to carry out the transesterification process. The responses were improved by varying and optimizing the essential parameters. The molar ratio (1 : 1 to 1 : 6), catalyst concentrations of 0.1 to 2.0 wt%, temperatures (30–$60^0$C), and time durations of 1 to 4 hrs were used. Finally, the methanol to oil molar ratio is kept at 5 : 1 to provide an efficient reaction on the conversion of triglycerides to FAME (fatty acid methyl ester) during the transesterification process. This matches with the literature findings [9, 19]. Base catalyzed transesterification (KOH) was performed in a 250 mL conical flask with a magnetic stirrer. In a flask, 60 mL of fat were added, along with 6g of potassium hydroxide dissolved in 300 mL of methanol. The best yield was observed for 90 min of stirring at a temperature of $55^0$C. The liquid was transferred to a separator funnel and the glycerol separated. To eliminate excess methanol, the reaction mixture was heated for a specific amount of time, cooled, and distilled. The yield under these conditions with the KOH catalyst was obtained at 48.5%. More water formation is limiting the yield of biodiesel.

WAF was transesterified using a concentrated sulfuric acid catalyst (2wt %) at 60°C on a shaker at a uniform speed of 300 rpm. The reaction mixture was heated for 2 hrs, cooled, and distilled to remove excess methanol. The obtained mixture consisted of glycerol and methyl esters (biodiesel). It was separated into two layers using a separating funnel. The upper oil layer (biodiesel) was separated and washed with hot water (50°C) until the washing was neutral. The biodiesel product was obtained by separating water. A biodiesel yield (wt%) relative to the weight of fat was estimated. The obtained biodiesel yield was 65.7%. It was identified that the acid catalyst yielded more in comparison to the base catalyst. The reason might be that the acidic catalyst is neutral to free fatty acids (FFA), thus showing better outcomes for the transesterification of fats. Figure 3 gives a glimpse of the experimentation.

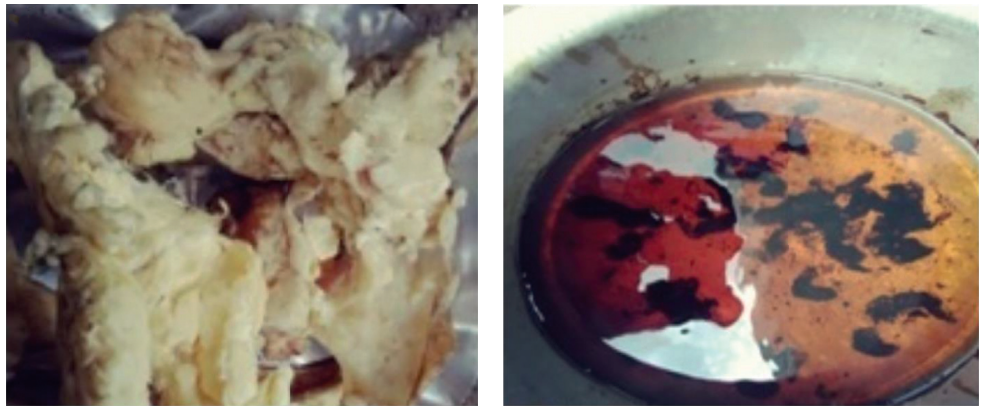
Table 1: Properties of fat extracted.

| Properties | Values |
|---|---|
| Density (g/l) | 0.91 |
| Kinematic viscosity ($mm^2/s$) | 46.3 |
| CV (MJ/Kg) | 38.58 |
| Acid value (mg KOH/g) | 1.14 |
| Flash point ( C) | 45 |

*3.3. Physiochemical Characteristics of Biodiesel.* Table 2 shows the physicochemical properties of biodiesel made; in order to determine the implementing feasibility of the produced fuel, these values were compared ASTM standard limits.

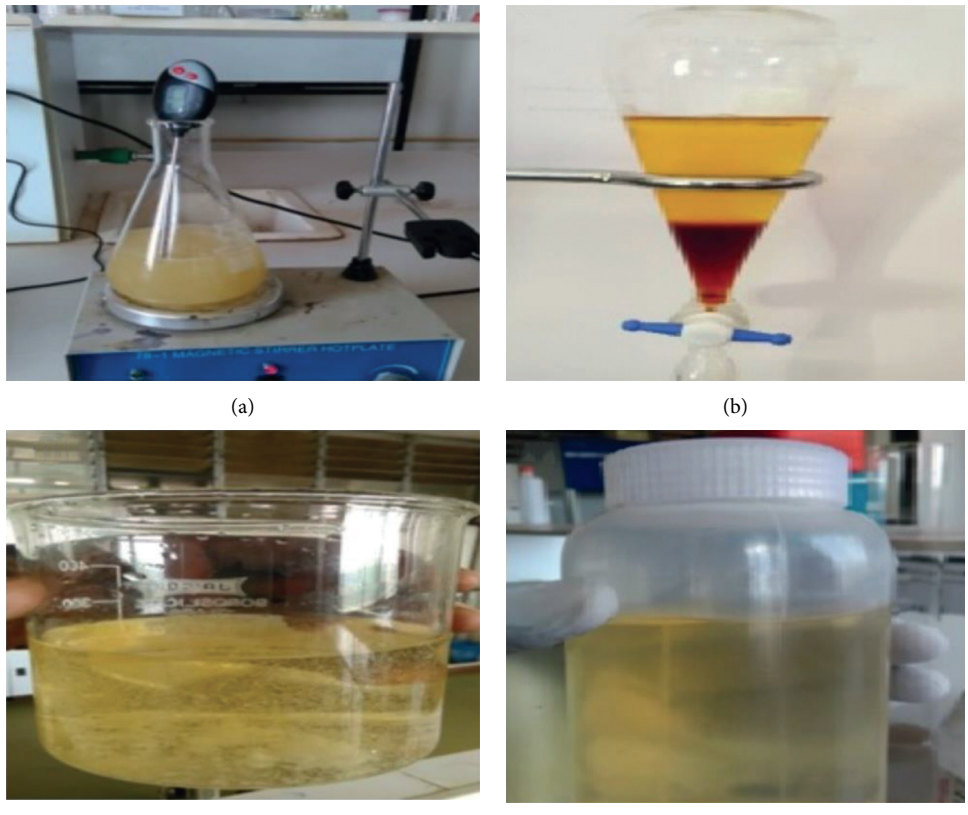
*3.3.1. Base Catalyzed Biodiesel.* The density of the biodiesel (0.835 g/l) was nearly identical to that of regular diesel (0.8326 g/l) and the viscosity is 8.35 $mm^2$/sec, indicating good atomization and full combustion of the biodiesel inside the engine and a longer engine life. The ASTM standard establishes a maximum acid value of 0.5 mg/g. The present analysis indicated that the base catalyzed WAF derived biodiesel has an acid value of 0.497 mg KOH/g. The acid number of the biodiesel (0.497 mg KOH/g) was a little higher than that of petrodiesel (0.35) but it does not harm the engine parts. The calorific value (CV) of any fuel is critical because a greater calorific value signifies more power production to power an engine. The calorific value of the generated biodiesel (40.21 MJ/Kg) is acceptable. The flash and fire points of biodiesel were considerably lower (68 C and 75 C) for the base catalyst. The cloud and pour points of the generated fuel were greater (-13 C and -7 C, respectively) than those of diesel. As a result of these cold flow characteristics, biodiesel generated using this method may be utilized in cold atmospheric circumstances. If the temperature of the atmosphere falls below $0^0$C, biodiesel additives may be necessary. Lower ash and carbon residue content results in less carbon deposition on engine components, extending engine life. The ash level is 0.013%. So the properties of the biodiesel were within an acceptable range such that the biodiesel can be used in an unmodified CI engine.

*3.3.2. Acid Catalyzed Biodiesel.* The density of the biodiesel (0.8165 g/l) was virtually similar to that of conventional diesel (0.8326 g/l), and the viscosity was 11.17 $mm^2$/sec. Biodiesel had a little higher acid number (0.4 mg KOH/g) within the allowable ASTM standards. The acid catalyst biodiesel has a calorific value of 42.63 MJ/Kg, which is higher than the base catalytic biodiesel produced. The flash and fire points of biodiesel were considerably higher (132 C and 143 C), making it preferable to petrodiesel. Greater flash and fire points minimize the possibility of an unanticipated fire danger. The flash point is an important indicator for fuel production that defines the lowest temperature at which the vapors of the material ignite. Therefore, this value indicates the safety of the prepared fuel for its transportation, storage, and handling. The produced fuel had higher cloud and pour



(a) (b)

Figure 2: (a) Dry animal fat collected; (b) fat oil generated from WAF.



(a) (b)

(c) (d)

Figure 3: (a) Crude biodiesel obtained; (b) glycerol separation; (c) filtered biodiesel; (d) biodiesel after distillation.

points (5 and 9 C, respectively) than diesel. Because of these cold flow properties, biodiesel produced with this technique may be used in cold weather. Less carbon deposition on engine components comes from lower ash and carbon residue levels, increasing engine life. The ash content of the biodiesel produced here is 0.01%. So the properties of the biodiesel were within an acceptable range such that the biodiesel can be used in an unmodified CI engine.

Table 2: Comparison of the physiochemical properties of biodiesel with ASTM standards.

| S.No | Property of fuel | Diesel | Biodiesel | | ASTM D6751 standards and test method |
|---|---|---|---|---|---|
| | | | Base catalyst | Acid catalyst | |
| 1 | Specific gravity (g/l) | 0.8326 | 0.835 | 0.8165 | 0.86–0.9 (D1298) |
| 2 | Kinematic viscosity ($mm^2$/sec) | 5.7 | 8.35 | 11.17 | 1.90–6 (D445) |
| 3 | Acid number (mg/KOH) | 0.35 | 0.49 | 0.4 | 0.5 (maximum) (D664) |
| 4 | Cetane number | 52.25 | 63.17 | 48.58 | 47 (minimum) (D613) |
| 5 | Calorific value (MJ/Kg) | 42.5 | 40.21 | 42.63 | 35–43 (D240) |
| 6 | Flash point ( C) | 67 | 68 | 132 | 93 (minimum) (D93) |
| 7 | Fire point ( C) | 74 | 75 | 143 | |
| 8 | Pour point ( C) | -13 | -13 | 5 | -15 to 10 (D97) |
| 9 | Cloud point ( C) | -9 | -7 | 9 | -3 to 12 (D2500) |
| 10 | Moisture content (vol %) | 0.01 | 0.068 | 0.023 | 0.05 (max) (D2709) |
| 11 | Ash content | 0.01 | 0.013 | 0.01 | 0.01 (D482) |

## 4. Conclusions

(i) $H_2SO_4$ and KOH catalysts were employed in biodiesel production from WAF by the transesterification method

(ii) The process parameters such as temperature, reaction time, molar ratio, and catalyst concentration are used in optimal conditions for the conversion of fats into FAME

(iii) Higher water formation is limiting the yield in KOH catalyzed process

(iv) Acid catalyst ($H_2SO_4$) was a more active catalyst than KOH to produce biodiesel

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## References

[1] I. W. Kularathne, C. A. Gunathilake, A. C. Rathneweera, C. S. Kalpage, and S. Rajapakse, "The effect of use of biofuels on environmental pollution-A review," *International Journal of Renewable Energy Resources*, vol. 9, no. 3, pp. 1355–1367, 2019.

[2] M. Ramos, A. P. S. Dias, J. F. Puna, J. Gomes, and J. C. Bordado, "Biodiesel production processes and sustainable raw materials," *Energies*, vol. 12, no. 23, 2019.

[3] H. Dagne, R. Karthikeyan, and S. Feleke, "Waste to energy: response surface methodology for optimization of biodiesel production from leather fleshing waste," *Journal of Energy*, vol. 2019, Article ID 7329269, 19 pages, 2019.

[4] G. R. Srinivasan, S. Palani, R. Jambulingam, and V. Shankar, "Effect of dominant fatty acid esters on emission characteristics of waste animal fat biodiesel in CI engine," *Frontiers in Energy Research*, vol. 7, no. JUN, pp. 1–13, 2019.

[5] S. Nanda, R. Rana, P. K. Sarangi, A. K. Dalai, and J. A. Kozinski, "A broad introduction to first-, second-, and third-generation biofuels," in *Recent Advancements in Biofuels and Bioenergy Utilization*, pp. 1–25, 2018.

[6] L. Carrino, D. Visconti, N. Fiorentino, and M. Fagnano, "Biofuel production with castor bean: a win-win strategy for marginal land," *Agronomy*, vol. 10, no. 11, 2020.

[7] D. Firemichael, A. Hussen, and W. Abebe, "Production and characterization of biodiesel and glycerine pellet from macroalgae strain: cladophora glomerata," *Bulletin of the Chemical Society of Ethiopia*, vol. 34, no. 2, pp. 249–258, 2020.

[8] F. Anguebes-Franseschi, A. Bassam, M. Abatal et al., "Physical and chemical properties of biodiesel obtained from amazon sailfin catfish (Pterygoplichthys pardalis) biomass oil," *Journal of Chemistry*, vol. 2019, Article ID 7829630, 12 pages, 2019.

[9] R. Karmakar, K. Kundu, and A. Rajor, "Fuel properties and emission characteristics of biodiesel produced from unused algae grown in India," *Petroleum Science*, vol. 15, no. 2, pp. 385–395, 2018.

[10] J. Rodríguez-Fernández, J. J. Hernández, A. Calle-Asensio, Á. Ramos, and J. Barba, "Selection of blends of diesel fuel and advanced biofuels based on their physical and thermochemical properties," *Energies*, vol. 12, no. 11, 2019.

[11] G. R. Srinivasan, V. Shankar, and R. Jambulingam, "Experimental study on influence of dominant fatty acid esters in engine characteristics of waste beef tallow biodiesel," *Energy Exploration & Exploitation*, vol. 37, no. 3, pp. 1098–1124, 2019.

[12] Srinivasan, R. Gokul, and R. Jambulingam, "Comprehensive study on biodiesel produced from waste animal fats-A review," *Journal of Environmental Science and Technology*, vol. 11, no. 3, pp. 157–166, 2018.

[13] Srinivasan, R. Gokul, S. Palani, and R. Jambulingam, "Biodiesel production from waste animal fat using a novel catalyst HCA immobilized AuNPS amine grafted SBA-15," *Journal of Engineering Science & Technology*, vol. 13, no. 8, pp. 2632–2643, 2018.

[14] M. Ndiaye, A. Arhaliass, J. Legrand, G. Roelens, and A. Kerihuel, "Reuse of waste animal fat in biodiesel: biorefining heavily-degraded contaminant-rich waste animal fat and formulation as diesel fuel additive," *Renewable Energy*, vol. 145, pp. 1073–1079, 2020.

[15] A. Keskin, M. Şen, and A. O. Emiroğlu, "Experimental studies on biodiesel production from leather industry waste fat and its effect on diesel engine characteristics," *Fuel*, vol. 276, no. April, 2020.

[16] F. Toldra-Reig, L. Mora, and F. Toldra, "Applied sciences trends in biodiesel production from animal fat waste," *Applied Sciences*, vol. 10, no. 3644, pp. 1–17, 2020.

[17] P. Hariprasath, V. Vijayakumar, S. T. Selvamani, M. Vigneshwar, and K. Palanikumar, "Some studies on waste animal tallow biodiesel produced by modified

transesterification method using heterogeneous catalyst," *Materials Today Proceedings*, vol. 16, pp. 1271–1278, 2019.

[18] M. Catarino, E. Ferreira, A. P. Soares Dias, and J. Gomes, "Dry washing biodiesel purification using fumed silica sorbent," *Chemical Engineering Journal*, vol. 386, Article ID 123930, 2020.

[19] Y. H. Tan, M. O. Abdullah, C. Nolasco-Hipolito, N. S. A. Zauzi, and G. W. Abdullah, "Engine performance and emissions characteristics of a diesel engine fueled with diesel-biodiesel-bioethanol emulsions," *Energy Conversion and Management*, vol. 132, no. September 2018, pp. 54–64, 2017.